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Abstract	This paper introduces a series of experiments with the objective of assessing the influence of color in emotion regulation. For this sake, images with one single color or one single dominant color are shown to a set of participants who take part in the experimentation. Firstly, the architecture of the color emotion regulation system is introduced. The methodology for color emotion recognition is based on a novel approach of both direct and indirect emotion evaluation. Then, the experimental setup is discussed together with the testing procedure. The tests are based on questionnaires for emotional state evaluation, color preference and personality. Lastly, the experimental results are described and discussed.

Keywords (separated by '-')	Color - Single-colored images - Emotion regulation

Experimentation on Emotion Regulation with Single-Colored Images

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Abstract. This paper introduces a series of experiments with the objective of assessing the influence of color in emotion regulation. For this sake, images with one single color or one single dominant color are shown to a set of participants who take part in the experimentation. Firstly, the architecture of the color emotion regulation system is introduced. The methodology for color emotion recognition is based on a novel approach of both direct and indirect emotion evaluation. Then, the experimental setup is discussed together with the testing procedure. The tests are based on questionnaires for emotional state evaluation, color preference and personality. Lastly, the experimental results are described and discussed.

Keywords: Color · Single-colored images · Emotion regulation

1 Introduction

Nowadays, much attention is being paid to emotional well-being of the ageing people [1,2]. In this sense, it is known that the quality of life of older people depends on their emotional interpretation to daily facts and events [3]. Some other relevant aspects in well-being are the everyday social, physical, mental and financial aspects. Although the quality of life can be affected in a negative way by some factors such as specially feeling lonely, poor overall health, self-care capacity limitations, and worry about financial resources, the older adults show high possibilities of emotion regulation. Findings in ageing literature demonstrate that older adults are more effective at regulating emotions in comparison to young adults (e.g. [4,5]), and they are more motivated to suppress interpersonal tensions [6]. These findings also show that color is a parameter that influences on their emotional state. Therefore, color should be well employed in favor of the people of this age group.

Indeed, color is a basic omnipresent factor, which relation with emotion has been demonstrated and discussed in the scientific literature for affective computing [7,8]. Many authors highlight that a certain color can be an additional

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factor for emotion elicitation and regulation. There are four possible explanations for the associations between color and emotions. They include references to metonymic and metaphoric, thinking, formation of specific emotional reactions for color perception, and sharing connotative structure in the language for color and emotion terms [9].

For instance, some colors are strongly associated with emotions [9,10]. Green is related to envy and relaxation; blue is associated with relaxation and sadness. Red, for example, has both positive and negative impressions, as it is known to be a color of positive activity, dominance and passion. It has also been is associated with arouse, excitement, and stimulation [11]. In Africa, red color is related to anger and triggers more negative emotions [12].

This is why color appears as an excellent tool of emotional modulation. Emotion regulation was initially supposed to be an ability to control the expression of negative emotions, and their suppression. Nevertheless, in terms of affective computing, this can be viewed as a complex phenomenon which widens social competence. It also affects the ability to form and maintain interpersonal relationships, which is of great importance for the health and well-being of ageing adults. Color constantly and imperceptibly affects the emotions of people. A personalized selection of colors would allow to regulate emotions with the aim to enhance positive emotions. Colored environments, where older adults stay, can help in inducing an emotion. The study (experimentation) described in this paper is aimed to discover new relations between color and emotions.

2 Relation Between Color and Emotions

A considerable number of research papers on the evaluation of the relation between color and emotions have been carried out so far. Moreover, the effect of color on the emotional state can be measured indirectly by means of affective semantic words and word combinations [13–15].

A seminal methodology suggests to rate a given word in a scale between two poles, which are semantic terms [16]. After that, factor analysis is used to detect the principal dimensions and the value of each word on the dimensions. With the purpose to study color emotion, factor analysis is usually applied [15]. And, if it fails, independent component analysis is used with intrinsic statistical properties of data such as kurtosis. Factor and correlation analysis (e.g. [13–15,17]) and ANOVA (e.g. [18–20]) are the most widely used classification methods for color-based emotion regulation.

It is important to note that some other findings demonstrate that color features like chroma, hue or lightness cause an impact on emotions [21–23]. Indeed, it has been proved that the chromatic palette contains emotionally charged information, as opposed to the achromatic one [23]. Lightness and chroma of color appear to dominate on most of the color emotion pairs, although the degree of their influence is small in some cases [21]. On the contrary, the hue of a color does not affect the emotional state of the participants of the described test. Similar results that confirm these findings [21] are obtained in another work [11].

Another approach points that older observers show strong preference to colors with higher chroma while younger people prefer achromatic colors [13].

Moreover, with respect to particular colors, a series of experiments conclude that stimulating effects are provoked by pink and yellow color samples; green elicits the feelings of excitement, relaxation and vividness as well as boredom and depression; blue is associated with calmness and coldness; red is stated as tiring and depressive, and together with violet they are named as striking colors [11]. The author of the experiments also finds a positive emotional response to black color for aged adults. In addition, strong colors (especially red) and patterns put the brain into a more excited state and may provoke severe changes in the behavior of introvert persons or people in bad mood [24]. But, the participants in this test feel more positive in the red room than in the blue one, as well as they feel more self-control in a room painted in gray. In another experiment on color emotion [25], the green color attains the most positive emotions, followed by yellow and blue.

3 Color Emotion Recognition

3.1 Methodology for Color Emotion Recognition

At the beginning of the experiment, each participant is due to pass a *Personality Test* with the aim to evaluate the characteristics of his/her personality. Also, an *Emotional State Test* has to be performed before and after each *Color Emotion Test*. Figure 1 shows the sequence in which the color emotion evaluation is carried out. In first place, the emotional state of the participant is evaluated with the Positive and Negative Affect Schedule (PANAS) scales. After that, the proper *Color Emotion Test* is passed. Emotion identification, as it is demonstrated in Fig. 1, is achieved as a result of the outcomes of both tests. The *Personality*

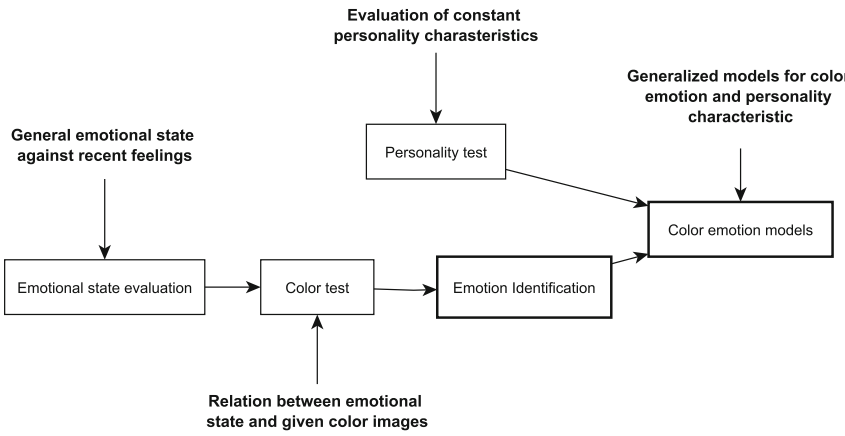

Fig. 1. The overall testing procedure.

Test, namely the NEO Five Factor Inventory, can be carried out before or after the *Color Emotion Test*. Finally, the generalized models for color emotion and personality characteristic are calculated.

PANAS Questionnaire. The Positive and Negative Affect Schedule (PANAS) scales test is a self-reported questionnaire to evaluate emotional states [26]. As aforementioned, this test is used as the *Emotional State Test*. More concretely, PANAS comprises 2 dimensions or factors: one with 10 items related to positive, and another with 10 items related to negative affect. The evaluation is performed with a set of ten positive and ten negative adjectives for every dimension. PANAS enables to evaluate affect changes as it consists of two parts: the first one aims to evaluate mood during the last week, and the last part rates mood in general. The scale is Likert-type, having to choose from 1 ("Strongly disagree") to 5 ("Strongly agree").

NEO-FFI Questionnaire. The NEO Five Factor Inventory (NEO-FFI) is the short version of the questionnaire NEO-PPI [27]. It is an instrument to evaluate the main personality factors. So, it is used in our approach as the *Personality Test*. It consists of 60 items, providing 12 items for each of the following 5 personality dimensions: "Neuroticism", "Extraversion", "Openness to experience", "Conscientiousness", and "Agreeableness". The scale is again Likert-type from 0 ("Totally disagree") to 4 ("Totally agree"). PANAS as well as NEO-FFI are conducted in order to know the effect that mood and personality can have on the *Color Emotion Test*.

Color Emotion Test. The *Color Emotion Test* supposes that a participant observes a single-colored picture during the exposition time, and evaluates his/her impression felt. In this case, really one-colored images as well as images composed of ne dominant color are provided. While a color is perceived, the brain links or associates it with a specific emotion or emotions [17]. This phenomenon is known as color emotion. Thus, an emotion can be described with semantic words, such as "Stressful", "Warm", "Passive" or "Bored". The experiment is inspired by a series of previous research works (e.g. [17,21,22,28–30]). The novelty here is that our proposal has the advantage that it evaluates both direct and indirect information about the effect of color on emotions. On the one hand, indirect information is obtained from the semantic words ("Tension", "Temperature", "Amusement" and "Attractiveness"), whereas direct information is gotten through emotional items ("Joy", "Fear" and "Sadness"). Thus, it is possible to measure the relation between the direct and indirect evaluators.

3.2 Architecture for Color Emotion Regulation

With the aim to embody the proposed experiment, a complete color emotion regulation system (CERS) has been created. The CERS belongs to an organiza-

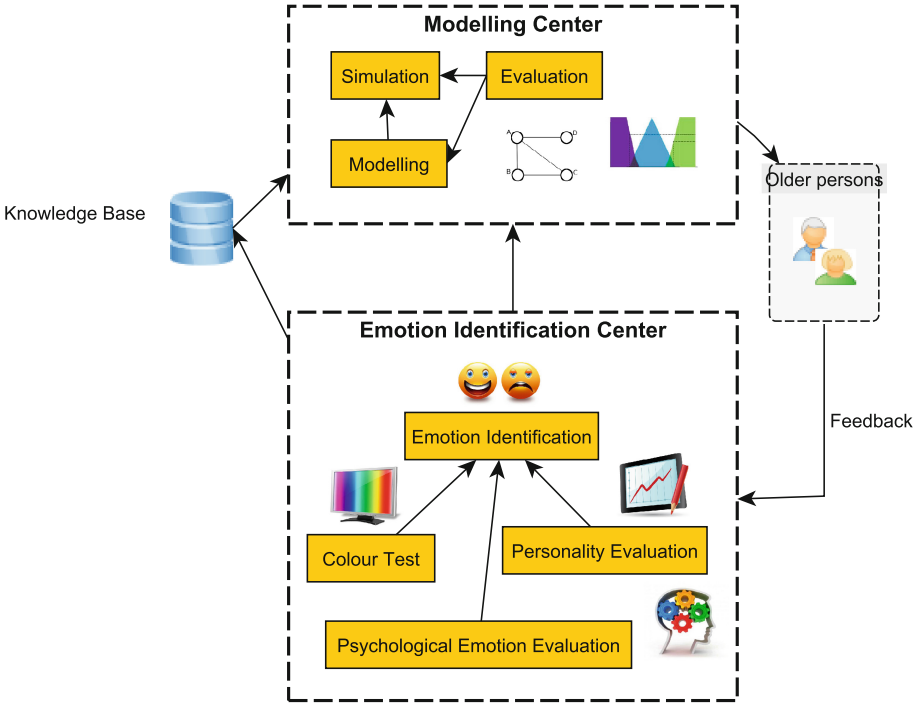

Fig. 2. The architecture of the color emotion regulation system (Color figure online).

tional type, and it is virtually and logically organized into a leveled architecture. It consists of the following modules (see Fig. 2):

- "Emotion Identification Center", which consolidates information from the incoming independent sources. Within this center, data preprocessing, identification, and classification tasks are performed. Here, the initial data are revised to identify errors, outliers, gaps, and duplications. An emotion is identified within this layer, and data are stored in a knowledge base (KB). "Emotion Identification Center" is the module that really interacts with the user and carries out the testing procedure. The three types of tests are performed at this level, including the *Color Emotion Test*, the *Emotional State Test*, and the *Personality Test*. The results of these tests are consolidated, and the resulting emotion is identified.
- "Modeling Center". The aim of this center consists in discovering of models that best describe relations between emotions and colors. Several data mining techniques are used for modeling, including decision trees and fuzzy logic, among others. First, the models are evaluated, and the best ones are selected, and they pass for further processing. Second, the selected models undergo simulations. Lastly, the simulation outcomes are evaluated.

4 Color Emotion Test: Methodology and Results

4.1 Methodology

A preliminary pilot test for 10 persons aged between 65 and 75 years, males and females in equal parts, has been carried out. The experiment is carried out in a room with white-colored walls. Each participant is placed in front of a computer in this room. Figure 3 shows the main menu of the application that the participant interacts with. The sequence of letters *A1-A2-A3* shows the sequence of tasks for a test participant. The task *B* can be carried out apart.

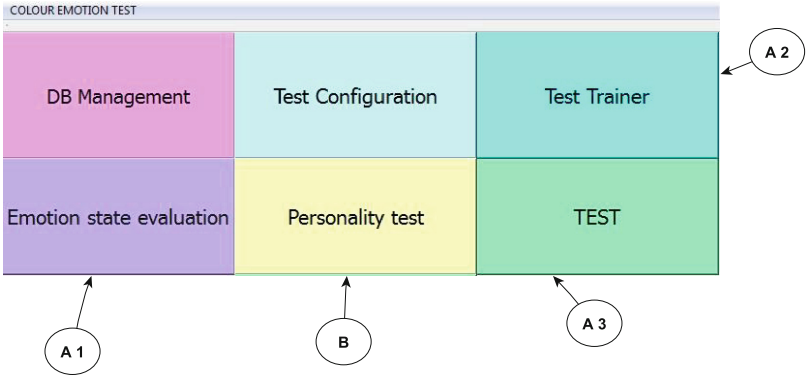

Fig. 3. The main menu of the application.

There are 10 colors that are used in this experimentation: blue, dark blue, brown, green, grey, purple, orange, red, pink, and yellow. The set of colored images is organized in such a way that each of the 10 colors is represented within 3 images, where one image is a plain single-colored one, and the two others are landscapes or images from nature with a marked dominance of a given color (see Fig. 4).

The test starts and goes on as described next:

1. The objectives of the tests are commented to the test participant.
2. After the instructions are given to the participant on how to answer to the *Emotional State Test* questionnaire, he/she starts the test.
3. Next, the participant receives information on how to carry out the *Color Emotion Test*, and he/she tries to answer two questions, doing the trial test with different images from an alternative image set.
4. After the training is over, the participant starts to answer the *Color Emotion Test*. Each participant is asked to judge about each one of 30 single-colored images.
   - A random image is presented during an exposure time of 4.5 s.

Fig. 4. Color images used in the experiment (Color figure online).

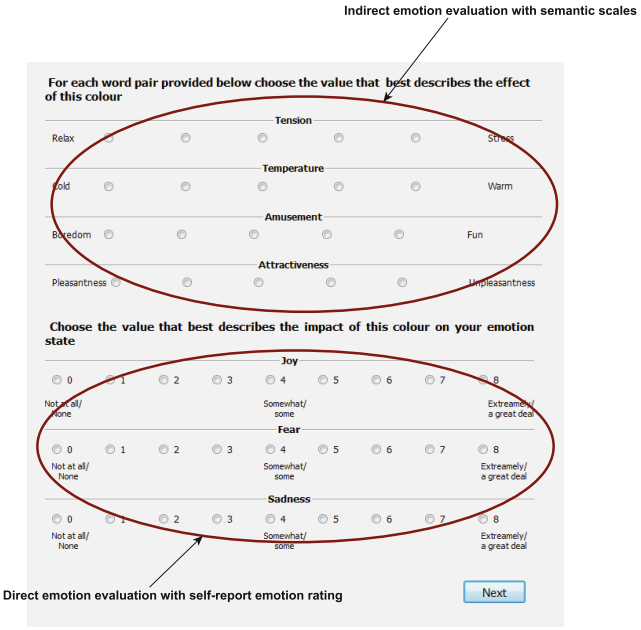

Fig. 5. The questions for emotion evaluation.

– A window with semantic and emotional scales appears (see Fig. 5), and the participant answers the questions by rating semantic words and evaluating emotions.
– The test ends when all the images have been evaluated in this manner.

The whole test duration varies from 30 to 60 min, where the *Emotional State Test* lasts between 5 and 10 min, the trial test between 5 and 15 min, and the *Color Emotion Test* between 20 and 40 min. There are pauses between these three tests, and it is recommended to make a pause every ten minutes while performing the *Color Emotion Test*. As already mentioned, the *Personality Test* can be carried out at any other moment, and it lasts about 30 to 60 min.

Figure 6(a) shows a screen shot with the questions to the NEO-FFI *Personality Test*, and Fig. 6(b) gives a view on a *Emotional State Test* questionnaire window.

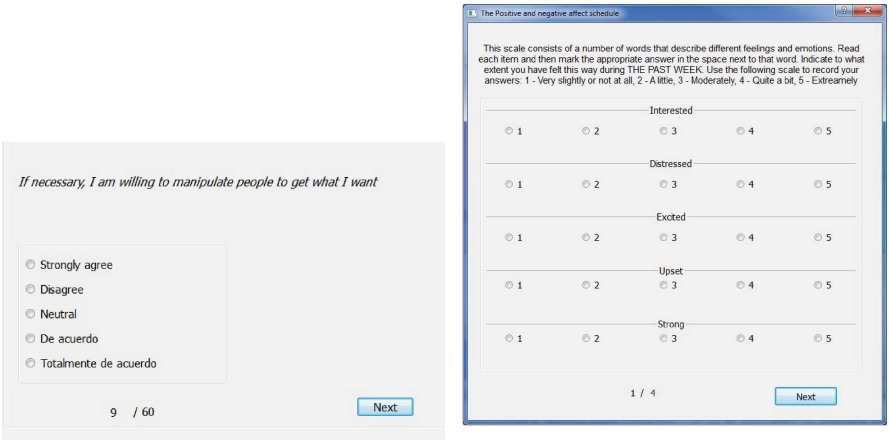

Fig. 6. Screen shots for the NEO-FFI and PANAS questionnaires. (a) Left: *Personality Test* (NEO-FFI) questionnaire window. (b) Right: *Emotional State Test* (PANAS) questionnaire window.

4.2 Results

The experiment outcomes show similarities in single-color perception on the emotional state of the participants. More concretely, semantic scale "Temperature" shows maximum values for colors red and yellow, and grey and red-colored images are rated at the top for the "Tension" scale. Purple, yellow, and pink colors are usually associated with the "Amusement" concept. The semantic scale "Attractiveness" shows that blue and purple colored pictures are preferred, followed by pink and yellow ones.

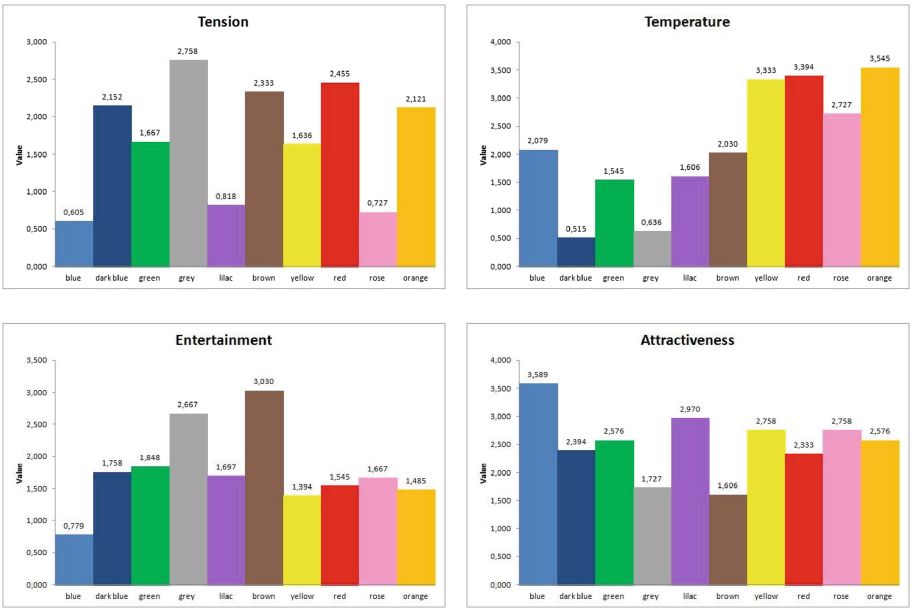

Fig. 7. Ratings for the semantic scales (Color figure online).

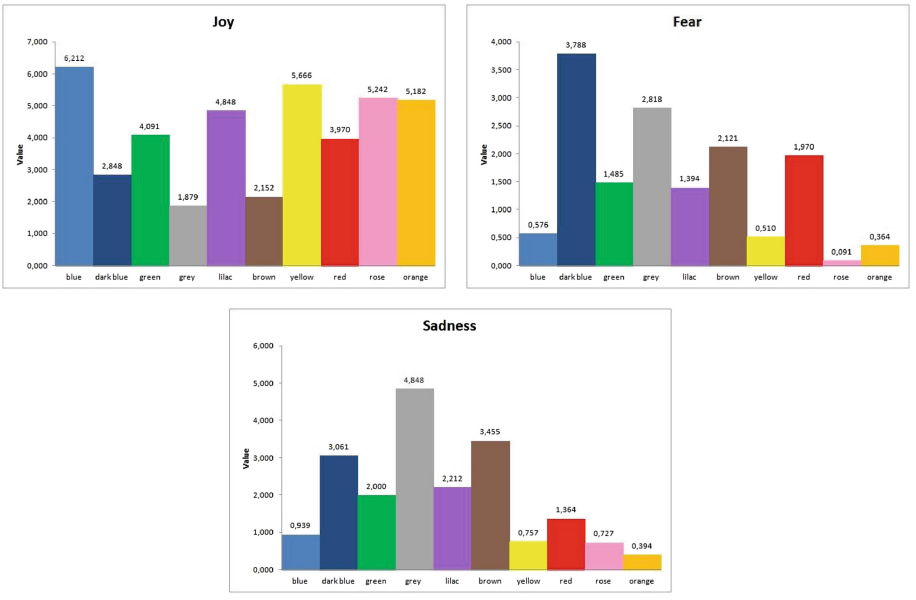

Fig. 8. Ratings for the emotion self-evaluation scales (Color figure online).

Referring to the emotions that have been experienced, the greater part of participants mark their extreme feelings for "Joy" after viewing images in blue, pink, yellow, and orange colors. The greater ranks for "Fear" are obtained for dark blue colored images, and the maximum rates for "Sadness" are obtained for gray colored images.

Figure 7 shows bar charts for the semantic scales. The group of warm colors (red, pink, orange, yellow) and the group of cold colors (gray, green, blue, dark blue) has shown a strong relation to the concept "Temperature" in general.

Figure 8 shows some bar charts for the emotional scales. The blue color (marked as the most pleasant and attractive, receives a major rate for the "Joy" concept together with warm colors. Actually, the concept of "Joy" appears to be multicolored, while "Sadness" and "Fear" are mostly high rated for the cold colors, and very low for the warm colors.

5 Discussion and Conclusions

The results obtained for single-colored images prove that there are strong relations between colors and emotions. These relations have been determined both with indirect and self-reported questionnaires. Moreover, the indirect evaluation with semantic scale "Attractiveness" discovers a strong preference for blue color, and the self-reported rating for blue colored images is highest for the "Joy" concept. In the same way, grey is the most unpleasant color with semantic scale "Attractiveness", and is related to the emotions of "Sadness" and "Fear". Warm colored images are associated with positive emotions, such as "Joy", while they are almost absent in the emotional scales "Sadness" and "Fear", with exception of the red color, which produces "Fear".

The future work has several directions. The first one consists in carrying out more experiments in order to enlarge our database and start data mining. The second way is related to the selection of the test images. As part of plain color images there are landscapes, and images with nature, which may influence not only with color, but with the proper subjective content. And, another directions is in adding additional semantic scales, such as "Dynamics" or "Harmony/Disharmony". Finally, our future plans include to make more experiments for ageing people from different countries, and to compare cultural components of color emotion results.

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